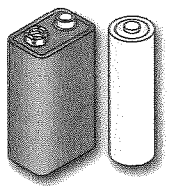
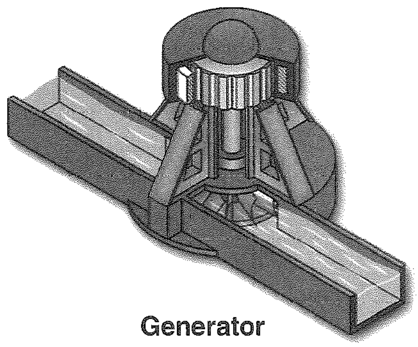
CHAPTER 1: BASIC COMPONENTS & CIRCUITS

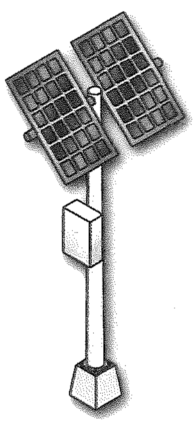
What is electricity? Nobody really knows. We only know how to produce it, understand its properties, and how to control it. It can be created by chemistry (batteries), magnetism (generators), light (solar cells), friction (rubbing a sweater), and pressure (piezoelectric crystals).



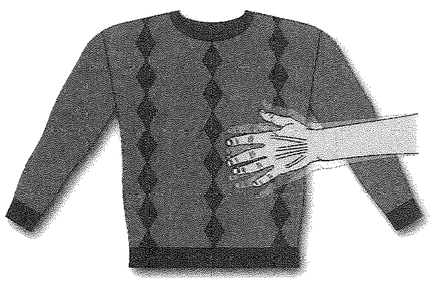
Batteries



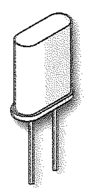
Generator



Solar Cells



Rubbing a Sweater

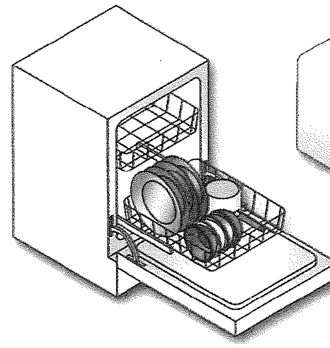


Piezoelectric Crystal

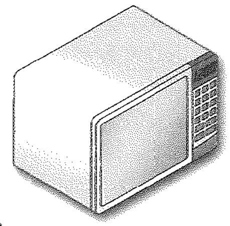
In this section you will learn about basic electrical components and circuits. By building circuits using Snap Circuits®, you will begin to understand the electrical world.

Electricity is energy that can be used to save us effort (electric toothbrushes and dishwashers), heat things (electric heaters and microwave ovens), make light (light bulbs), and send information (radio and television). But electricity can also be dangerous if abused (electric shock).

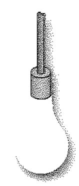
Electric Toothbrush



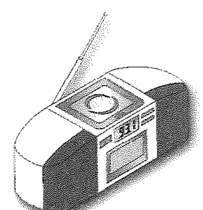
Dishwasher



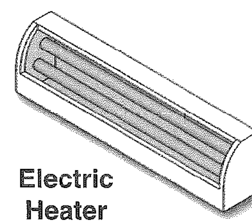
Microwave Oven



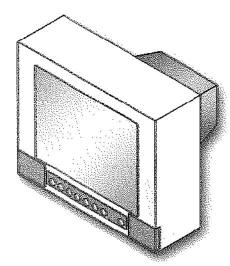
Light Bulb



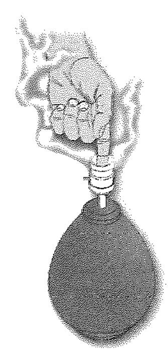
Radio



Electric Heater



Television



Electric Shock

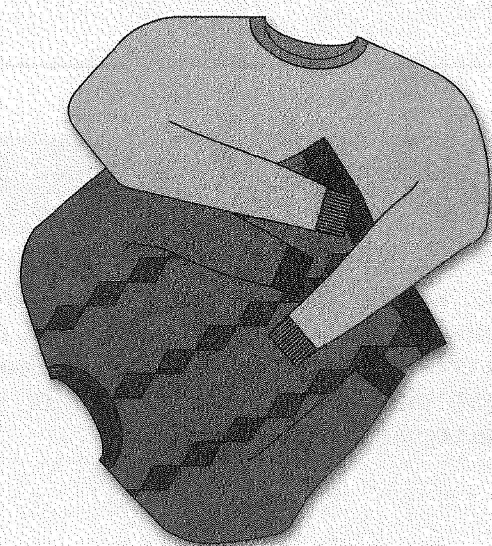
1-1 Electricity

The name electricity came from the Greek name for amber, the material in which electrical effects were first observed. What do you think of electricity as being? **Electricity** is one of the fundamental forces of nature. At its most basic level, it is an attraction and repulsion between sub-atomic (very, very, very, very tiny) particles within a material. This attraction/repulsion is referred to as an **electrical charge**; it is similar to and closely related to magnetism. These attractions/repulsions are extremely powerful but are so well balanced out at the sub-atomic level that they have almost no effect on our lives.

As an example, electrical attraction is about 1,000,000,000,000,000,000,000,000,000,000,000,000,000,000 times more powerful than gravity (gravity is what causes things to fall to the ground when you drop them). However electrical attraction is so completely balanced out that you don't notice it, while gravity effects are always apparent because they are not balanced out.

Gravity is actually the attraction between objects due to their weight (or technically, their mass). This effect is extremely small and can be ignored unless one of the objects is as big as a planet (like the earth). Gravity attraction never goes away and is seen every time you drop something. Electrical charge, though usually balanced out perfectly, can move around and change quickly.

For example, think about how two sweaters can cling to each other when you take them out of the dryer. This is due to an electric charge that has built up between them. There is also a gravity attraction between the sweaters, but it is always extremely small.



Electronics is the science of working with and controlling electricity. Many work-saving appliances like dishwashers, hairdryers, and drills are electrical but not electronic. Electronic products use electricity to control themselves, using parts like resistors, capacitors, and transistors. Electrical appliances are only controlled mechanically.

A good way to think of the difference between electrical and electronic products is to think about moving into a new house. Most products in the empty house are electrical (such as all the wiring and switches in the walls, rotary phones, dishwashers, electric ovens, air conditioners, most types of thermostats).

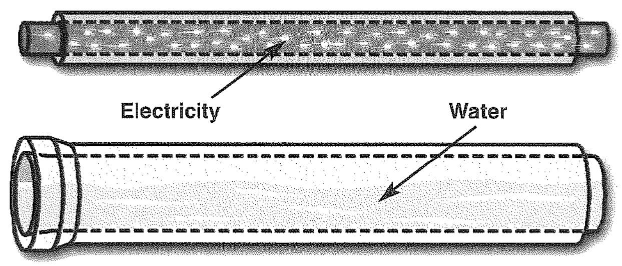
Most products you bring from your old house to your new house are electronic (such as TVs, computers, touch-tone phones, radios, most battery operated products), but not all (such as hairdryers, electric power tools).

Electricity is the movement of sub-atomic particles (with their electrical charges) through a material due to an electrical charge outside the material. Electricity will be easier to understand if you think of the flow of electricity through circuits as water flowing through pipes.

1-2 Wires

Wires can be thought of as large, smooth pipes that allow water to pass through easily. Wires are made of metals, usually copper, that offer very low resistance to the flow of electricity.

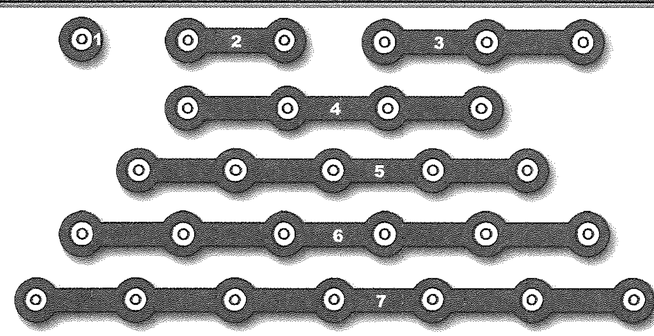
The **electric current** is a measure of how fast electricity is flowing in a wire, just as the water current describes how fast water is flowing in a pipe. It is expressed in **amperes** (A, named after Andre Ampere who studied the relationship between electricity and magnetism) or **milliamps** (mA, 1/1000 of an ampere).



With Snap Circuits® the wires you will use have been shaped into snap wire strips, to make interconnection easy. These work the same as any other wires you might find in your house, since they are made of metal.

Introducing New Parts

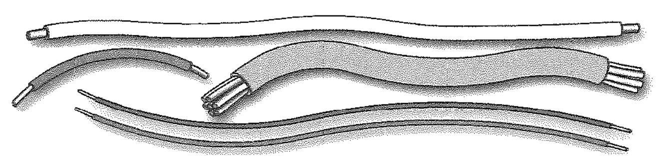
If you have the Snap Circuits® parts nearby then pull out the wires and look at them. They have numbers such as 2, 3, 4, 5, 6 or 7 depending on the length of the wire connection. There is also a 1-snap wire that is used as a spacer or for interconnection between different layers.



Wires can generally be as long as desired without affecting circuit performance, just as using garden hoses of different lengths has little effect on the water pressure as you water your garden. However there are cases where the length and size of a pipe does matter, such as in the water lines for your entire city or in an oil refinery. Similarly, wire length and size are important for electric power lines transporting electricity from a power plant in a remote area to a city, and in circuits used in radio or satellite communication.

If you were to look inside an electronic device in your home (make sure it's not plugged in) you might see a lot of wires of different colors. The actual wires are all the same color of metal, but they have a protective covering over them. The colors are used to easily identify which wire is which during assembly and repair of the circuit.

The covering is also used to prevent different parts of a circuit from connecting accidentally.

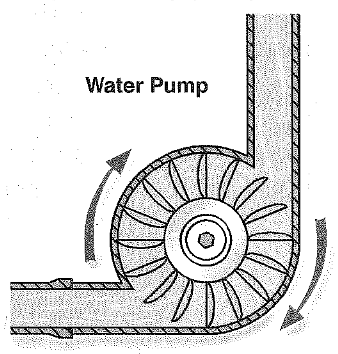


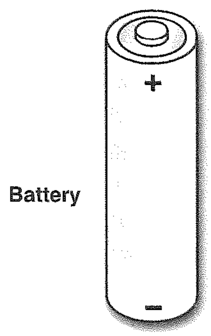
Try to imagine the total length of wire used in all the products in your home!

1-3 Batteries

To make water flow through a pipe we need a pump. To make electricity flow through wires we use a battery. A battery creates an electrical charge across wires. It does this by using a chemical reaction and has the advantage of being simple, small, and portable.

Voltage is a measure of how strong the electric charge from your battery is, and is similar to the water pressure. It is expressed in volts (V, and named after Alessandro Volta who invented the battery in 1800). Notice the "+" and "–" signs on the battery. These indicate which direction the battery will "pump" the electricity, similar to how a water pump can only pump water in one direction.



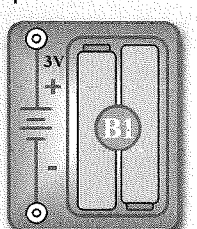


The 0V or "–" side of the battery is often referred to as "**ground**", since in house or building wiring it is connected to a rod in the ground as protection against lightning.

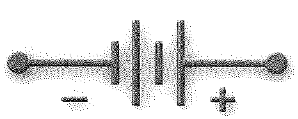
Battery power is much easier to use in electronics than the electricity that powers your home. This is because most electronic circuits only need a low voltage source to operate; all the electricity produced by your electric company comes at a higher voltage, which must be converted down. If a circuit is given too much voltage then its components will be damaged. It is like having the water in your faucet come out at higher pressure than you need, and it splashes all over the room. If water in a pipe is at too high of pressure then the pipe may burst. Batteries are selected to give your circuit just the voltage it needs.

Introducing New Parts

Your Snap Circuits® uses two sets of two 1.5V batteries in a holder (snap part B1, actual batteries are not included). Notice that just to the right of the battery holder pictured below is a symbol, the same symbol you see on the battery holder. Engineers are not very good at drawing pictures of their parts, so when engineers draw pictures of their circuits they use symbols like this to represent them.



Battery Holder (B1)

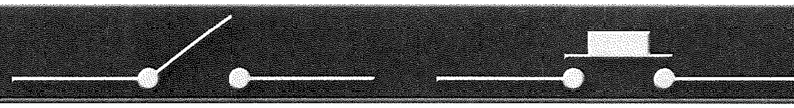


Battery Symbol

Batteries are made from materials like zinc and magnesium dioxide, electricity flows as these react with each other. As more material is used up by the reaction, the battery voltage is slowly reduced until eventually the circuit no longer functions and you have to replace the batteries. Some batteries, called rechargeable batteries (such as the batteries in your cell phone), allow you to reverse the chemical reaction using another electric source. That way the batteries can last through years of use.

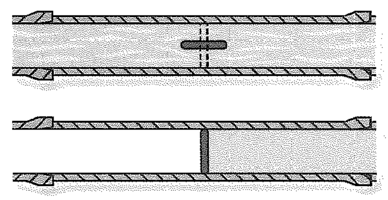
Try to count how many batteries are in your home, your count will probably be low. Many products that use your house power also have batteries to retain clock or programmed information during brief power outages (such as computers and VCRs).

1-4 The Switch

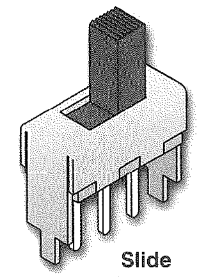


Since you don't want to waste water when you are not using it, you have a faucet or valve to turn the water on and off. Similarly, you use a switch to turn the electricity on and off in your circuit. A switch connects (the "closed" or "on" position) or disconnects (the "open" or "off" position) the wires in your circuit.

Closed Position



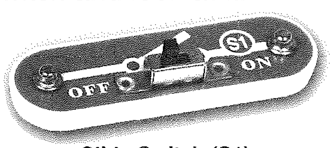
Open Position



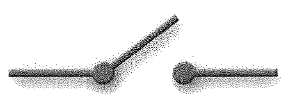
Slide Switch

Introducing New Parts

Just as the plumbing industry has a wide range of valves for different situations, there are many types of switches used in electronics. The type shown below is called a slide switch, because you slide it back and forth to turn it on and off. Snap Circuits® includes one of these (part S1), shown below. As with the battery, the slide switch is represented by a symbol, shown to its right. If you have the snap circuits parts nearby, take out the switch and look at it.



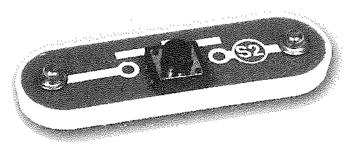
Slide Switch (S1)



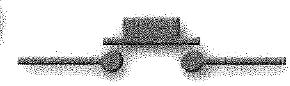
Slide Switch Symbol

Introducing New Parts

Another type of switch is the press switch, and Snap Circuits® also includes one of these (part S2). When you press down the two pieces of metal touch, so electricity can flow. When you let go of it, the electricity stops. Its symbol is marked on the snap part, though on many professional electronics drawings both slide and press switches use the symbol for the slide switch because they really perform the same function.



Press Switch (S2)

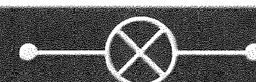


Press Switch Symbol

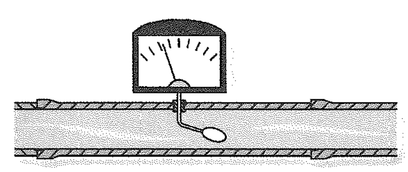
You can think of slide and press switches like the water faucet in your kitchen (which pours out water until you turn it off) and a water fountain in a school or movie theater (which only squirts out water as long as you are pressing the button).

Switches in modern electronics come in many diverse forms. Try to count how many are in your home or car; you will be amazed. There are slide, press, membrane, rotary, push-button, and other switches controlling nearly everything.

1-5 The Lamp



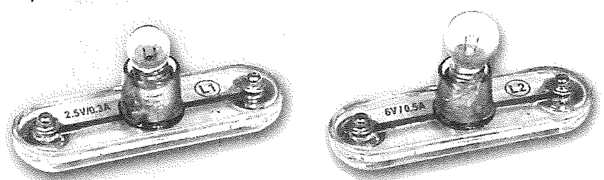
In a **lamp** electricity is converted into light, the brightness of the lamp increases as more electric current flows through it. You can think of a lamp as a water meter, since it is showing us how much current is flowing in a circuit just as a water meter shows how much water is flowing in a pipe.



Water Meter

Introducing New Parts

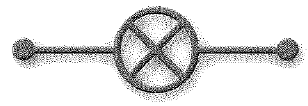
Snap Circuits® includes two different lamps (parts L1 and L2, shown below). If you have the parts with you, take them out and look at them.



2.5V Lamp (L1) 6V Lamp (L2)

Just as there are different types of water meters to work with different pressures and volumes of water, there are also different lamps. Lamp L1 is a low-pressure meter, and works with voltages (electrical pressures) of up to 2.5V. Higher voltages than that will damage the bulb, so always make sure to use the correct lamp. Lamp L2 is for higher pressures of up to 6V, and won't be nearly as bright as L1 if the pressure is only 2.5V.

The electrical symbol for a lamp is shown here, it is the same for both lamps but the voltage will be indicated as needed. The lamp sockets are the same for both parts; only the bulbs and markings are different.

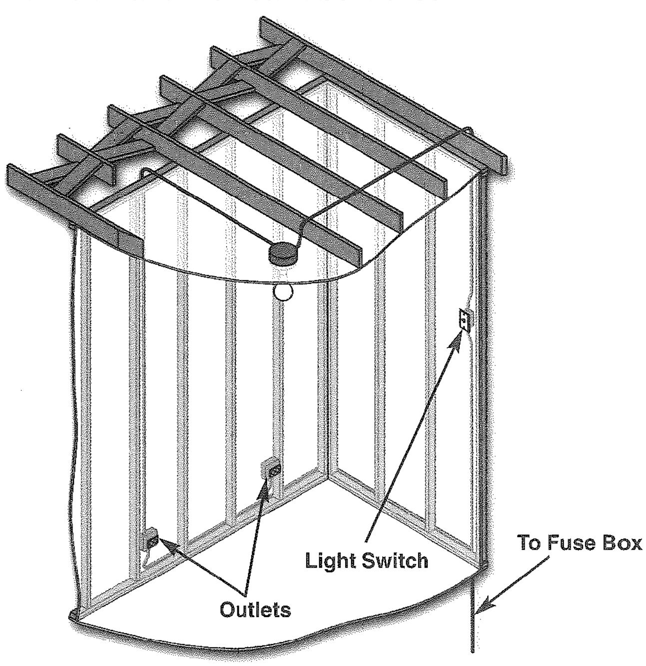


Lamp Symbol

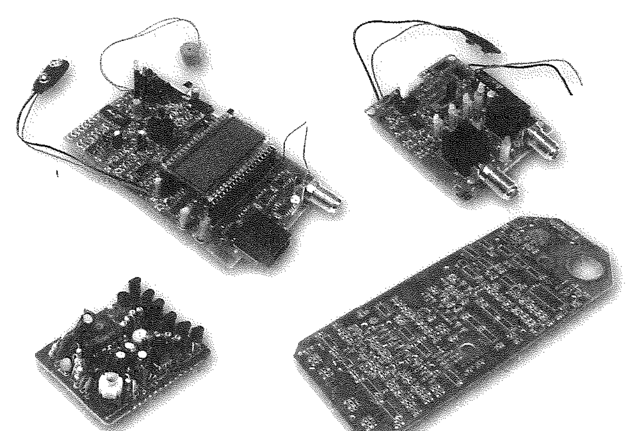
While occasionally lamps are used to indicate how much electricity is flowing in a circuit, they are mostly used to light our homes, businesses, and streets. Although scientists had been experimenting with electricity for years, the first practical use of electricity occurred when inventor Thomas Edison used it to light a bulb similar to these. For many years electricity was used almost exclusively for lighting. That has since changed. Now only a small percentage of the electricity produced in the United States is used for lighting with the rest going to a vast range of uses in everyday life that Edison would never have imagined.

1-6 The Base Grid

The water in your home flows through pipes mounted in the walls and floors of your home, and similarly the electricity in your house flows through wires mounted in the walls and ceilings of your home. But the wires in your walls take a lot of hard work to install and then can't be moved.



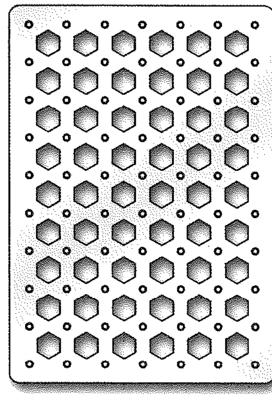
Most products that use electricity are small, easy to move, and easy to build. That is because they have almost all of their components and wires mounted on "circuit boards" such as these:



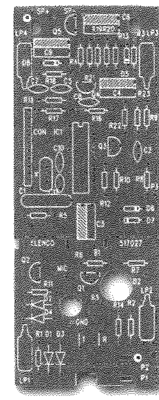
Boards like these are used in almost all electronic products, look inside any radio or computer and you will find them. Note that the "wires" connecting parts mounted on the circuit board are literally "printed" on the surface of the board; hence circuit boards all are called "printed circuit boards" or PCBs.

Introducing New Parts

In the same manner Snap Circuits® uses a clear plastic base grid with evenly spaced posts to mount the snap parts and wires and to keep them together neatly. It has rows labeled A-G and columns labeled 1-10 to easily identify points in your circuit. You don't need the base to build your circuits, but just try building one of the larger circuits without it! The base grid is shown here, next to a picture of a typical circuit industry board before parts are mounted.



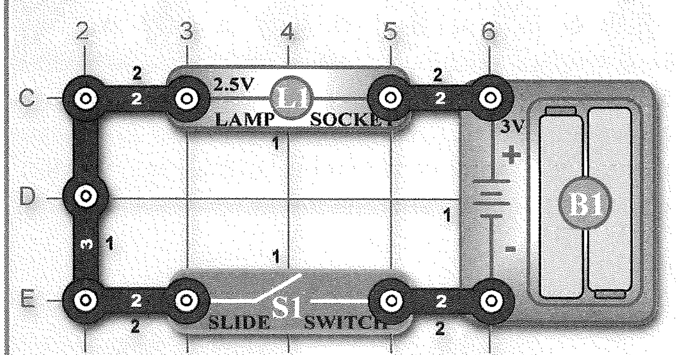
Base Grid

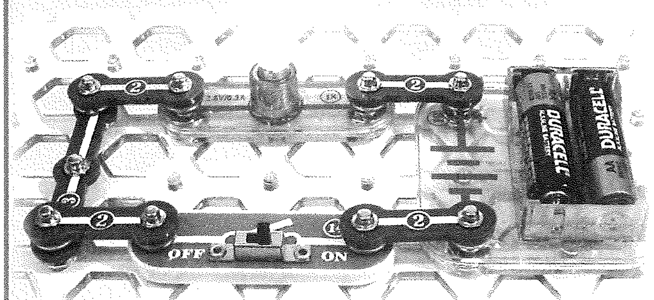


PC Board

Experiments

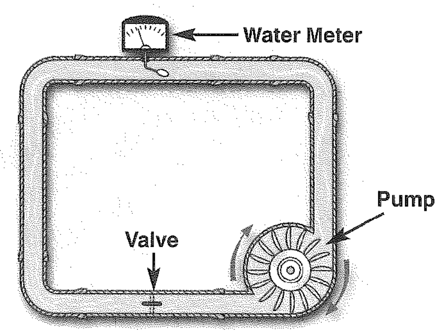
So far we've talked about wires, batteries, switches, lamps, and circuit boards; now it's time to put them together to form a circuit. Consider this circuit (which is project 1 on page 8 of the first project manual):





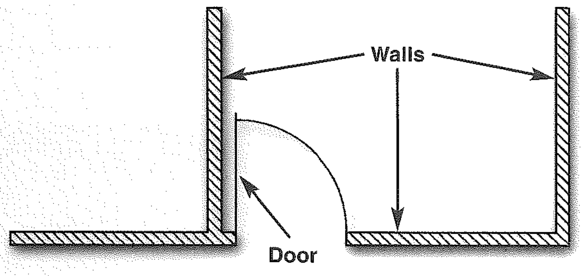
Turning on the switch turns on the lamp. This circuit is the same circuit used to turn on a lamp in your home. The only differences are the batteries are really power from the electric company, the lamp is larger and bright enough to light up the room, the switch is really a switch on the wall, and the snap wires are really wires in the wall and the cord to the lamp.

You can think of the electricity flowing through the battery, lamp, switch, and wires in the above circuit as if it were water flowing through a pump, water meter, valve, and pipes:

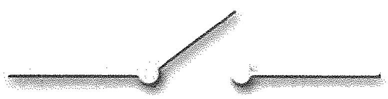


Note that each of the Snap Circuits® in the project manuals has a box next to it ☐ so that you can mark off the circuits as you build them.

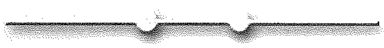
In electronics, the "on" position of a switch is also called the "closed" position. Similarly, the "off" position is also called the "open" position. This is because the symbol for a slide switch is similar to the symbol for a door in an architect's drawing of a room:



The electronics symbol for a slide switch should be thought of as a door to a circuit, which swings open when the switch is off. The "door" to the circuit is closed when the switch is on. This is shown here in drawings using the part symbols:



Open Switch (turned off)



Closed Switch (turned on)

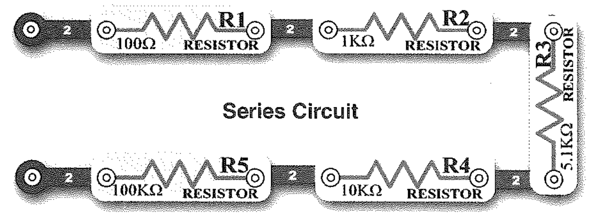
In case you haven't noticed, the batteries produce 3V and the lamp is made for voltages up to 2.5V. Don't worry, you will not damage your bulb. The voltage rating of the batteries (1.5V from each battery) is actually the voltage they produce when the electric current flowing from them is low, as the circuit current increases the voltage produced by the batteries is reduced. Think again of the lamp as a water meter - the lamp is bright so there must be lots of current flowing, hence the voltage is lower and the lamp is safe. You can see from the water diagram that with only a pump, an open valve, and a meter there is nothing to slow down the water flow and the pump will move the water as fast as it can.

Why does the battery voltage drop as current increases? Remember that a battery produces electricity from a chemical reaction. Not only is there a limited amount of the chemicals in a small battery (batteries slowly get weaker as you use them), but also not all of the material can react together at the same time.

If your instructor has a meter to measure voltage, ask him or her to measure the battery voltage with the switch on and off. You will see the voltage drop to under 2.5V when the switch is on.

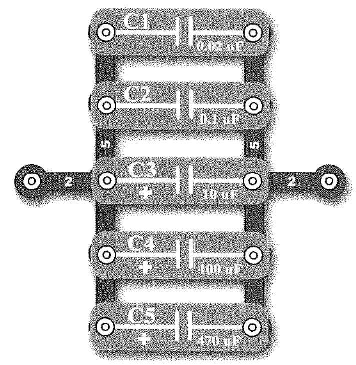
1-7 Series vs. Parallel Circuits

There are two ways of arranging parts in a circuit, in series or in parallel. Here are examples:

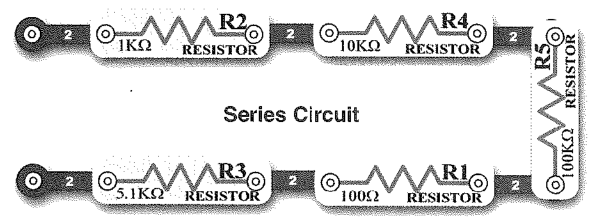


Series Circuit

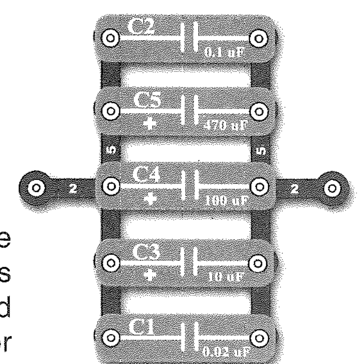
The parts within these series and parallel sub-circuits may be arranged in different ways without changing what the circuit does. So these sub-circuits are the same as the ones above:



Parallel Circuit

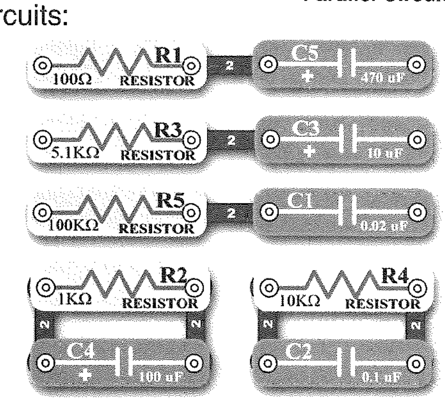


Series Circuit

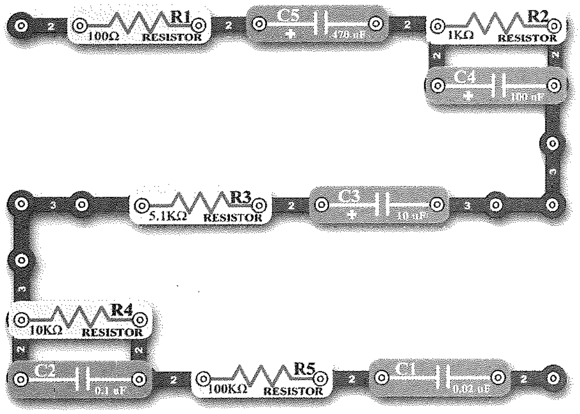


Parallel Circuit

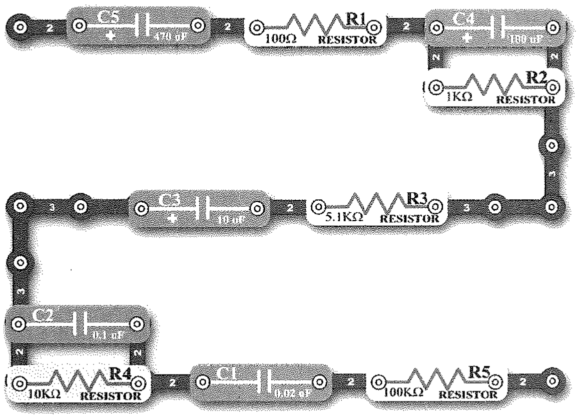
Large circuits are made of combinations of smaller series and parallel circuits. For example, these small sub-circuits:



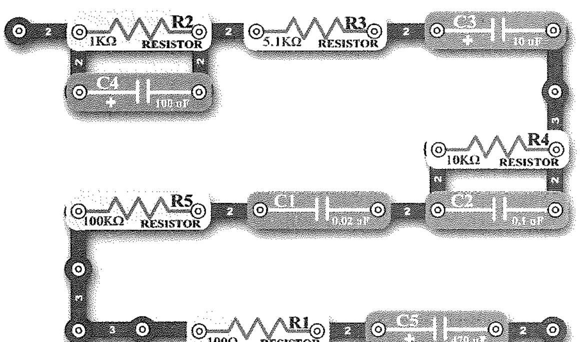
May be combined into this larger circuit:



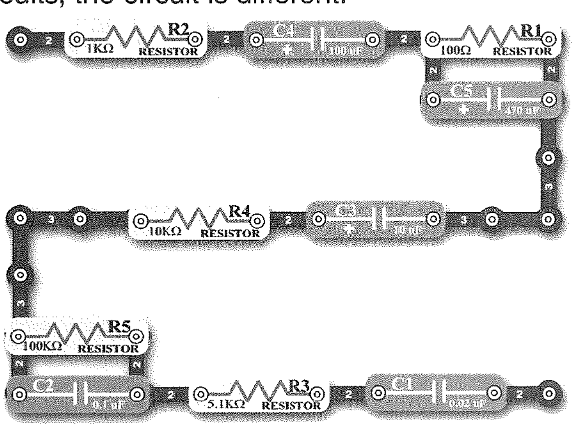
If you rearrange the parts in the sub-circuits, the circuit is still the same:



If you rearrange the order of the sub-circuits, the circuit is also the same:

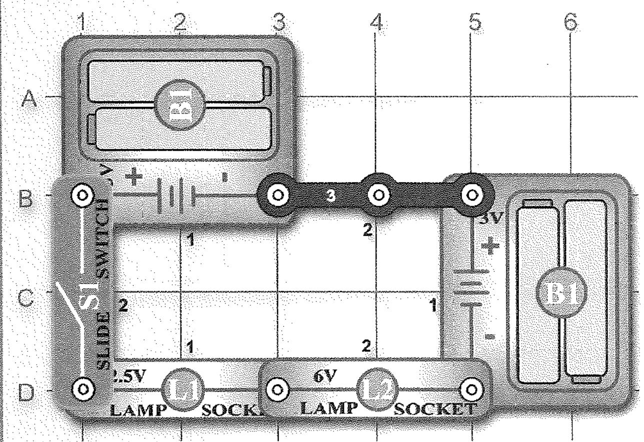


But if you rearrange the parts between sub-circuits, the circuit is different:



Experiments

Consider this circuit (which is project 152 on page 22 of the "Experiments 102-305" manual):



If the switch is on, both lamps will light. If one of the bulbs is broken then neither will be on, because the lamps are in series. The strings of small Christmas lights are wired in series; if one bulb is damaged then the entire string does not work.

This circuit uses two sets of batteries, these add together in a series circuit to produce 6V. Likewise, while 6V is well beyond the 2.5V rating of lamp L1, this voltage gets split between lamps L1 and L2 and so L1 will not be damaged. L2 is a 6V lamp made for higher voltage and current, so it will not be nearly as bright in this circuit as L1.

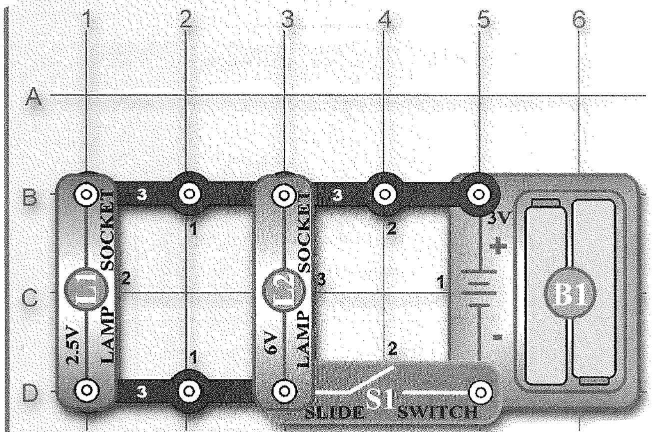
When the circuit has been off for a while, turn on the switch and watch the lamps closely. Notice how L2 takes longer to get bright while L1 gets very bright initially but becomes less bright as L2 turns on. Why?

Lamps like these are made with a special type of wire that gets hot enough to glow. L1 turns on faster because its wire heats up faster than L2's.

This effect may be easier to see if you replace one of the battery holders with a 3-snap wire.

Experiments

Consider this circuit (which is project 153):



If the switch is on, both lamps will light. If one of the bulbs is broken then the other will still be on, because the lamps are in parallel. Most of the lights in your house are wired like this; if a bulb is broken on one lamp then the other lamps are not affected.

In this circuit you could swap the locations of the lamps with each other (because they are both in parallel) or the batteries with the switch (they are both in series), but if you swap the switch with one of the lamps then the circuit will be different. All electric circuits are made up of combinations of series and parallel circuits, from simple ones like these to the most complex computers.

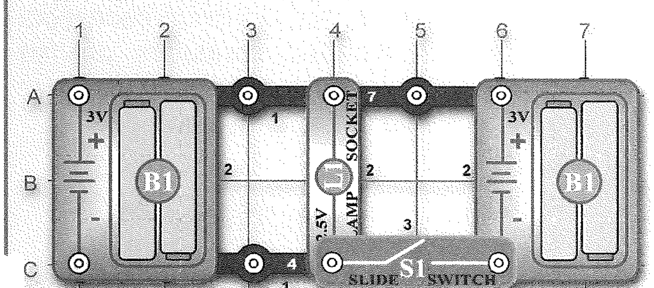
Note that in project 153 the lamps have the same brightness as in project 152 even though only one battery set is used. This is because the full battery voltage is applied to both lamps. This may seem more efficient than the method in project 152, but the current to light the lamps is the same so it is draining the batteries twice as fast.

For all of the Snap Circuits® projects, the parts may be arranged in different ways without changing the circuit. The order of parts connected in series or in parallel does not matter - what matters is how combinations of these sub-circuits are arranged together. For example, in project 152 you may swap the locations of the switch or lamps without affecting the circuit operation in any way because they are all connected in series.

The choice of whether to use a series or parallel configuration in a circuit depends on the application, but will usually be obvious. For example the overhead lights in the rooms of your home are all connected in parallel so that you can have light on in some rooms and off in others, but within each room the light and switch are connected in series so the switch can control the light.

Experiments

Now consider this circuit (which is project 103):



With the switch off, the lamp will be bright even with only one set of batteries connected. If the switch is turned on then the lamp will be even brighter. This will be more apparent if the batteries on the left side are weak and those on the right side are new.

Batteries are placed in parallel when the voltage is high enough but the circuit needs more current than one group of batteries can supply. Think of each battery as a storage tank that supplies water. If you put two in parallel, you can get more water (current), but the pressure (voltage) stays the same.

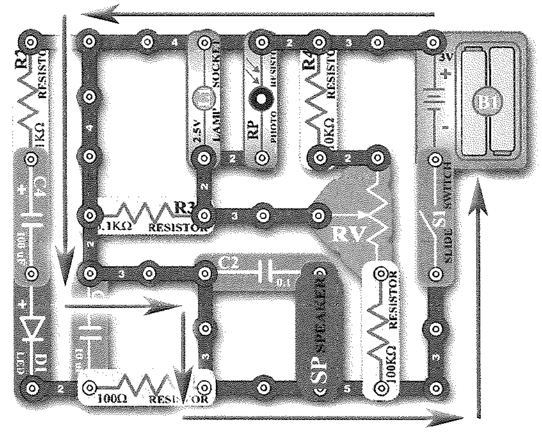
1-8 Short Circuits

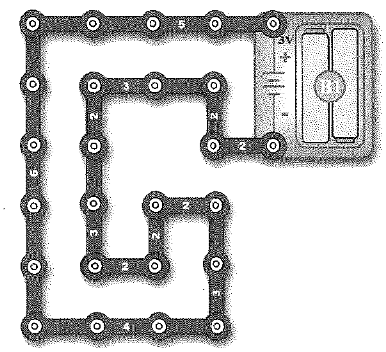
Every circuit will include a power source (the batteries), a resistance (which might be a resistor, lamp, motor, integrated circuit, etc.), and wiring paths between them and back. When wires from different parts of a circuit connect accidentally then we have a "short circuit". You've probably heard this term in the movies; it usually means trouble.

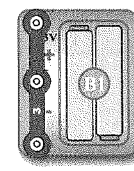
A short circuit is a wiring path that bypasses the circuit resistance, creating a no-resistance path across the batteries. This will damage components and/or quickly drain your batteries. Be careful not to make short circuits when building your circuits. Always check your wiring before turning on a circuit.

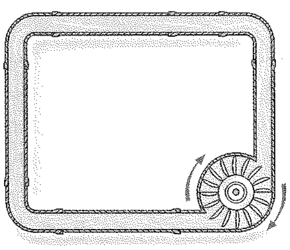
The name "short circuit" refers to how the current through the circuit bypasses (jumps around) other components in the circuit. It is the "easiest" path through the circuit, it is not always the "shortest".

Here are some examples:







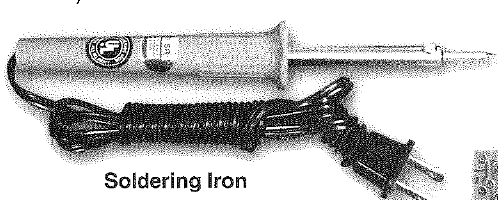


In a short circuit, there is nothing to limit the current in a circuit. However the chemical reaction in a battery cannot supply unlimited current, so the battery voltage drops to zero volts. This is called "overloading" the batteries. This overload produces heat and damages the batteries. Think of this as a pump pumping water in a loop as fast as it can until it burns out.

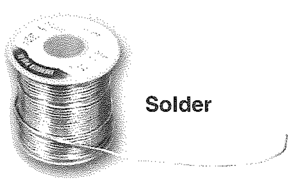
1-9 Solder

Solder is used to make electrical connections to components on a printed circuit board. It is a special metal made mostly of tin that melts at relatively low temperature (about 500°F). Solder is applied and melted around a joint where a connection is being made; it creates a solid bond between the metals.

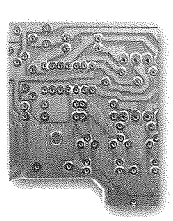
The placement of parts onto circuit boards and the application of solder to connect and hold them in place are usually done automatically with special machines. In fact, the microprocessors used in modern computers are so finely designed that they are almost impossible to solder by hand.



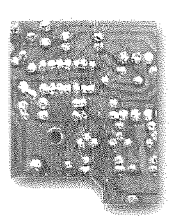
Soldering Iron



Solder



Before Soldering



After Soldering

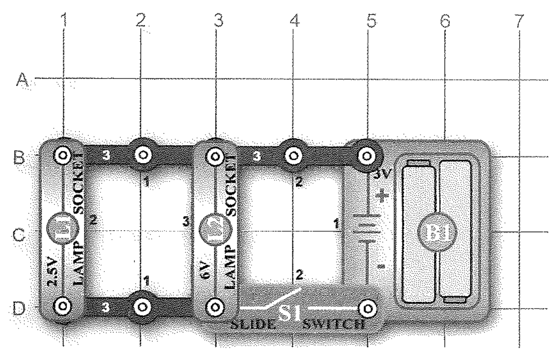
Soldering Machine

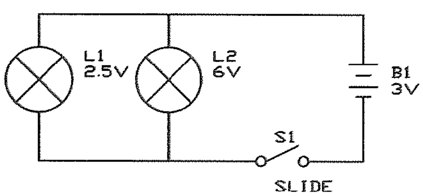
1-10 Schematics

The circuit diagrams in the Snap Circuits® manuals are easy to understand and build your circuits from. But what if you wanted to write down your own circuit? These diagrams are not very easy to draw. There are also many ways of building the same circuit. For example, you could use a jumper wire instead of a 2-snap wire.

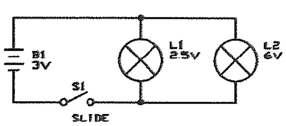
The Snap Circuits® diagrams give you more information than you really need. They tell you how to build it, when all you really need to know is how it will work. You can find your own way to build it.

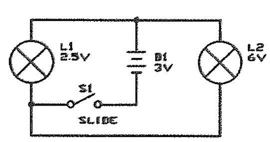
Notice the symbols marked on the parts. Those symbols are used in engineering circuit diagrams, which are called **schematics**. For example, snap circuits project 153 is shown here with an engineering schematic for it:

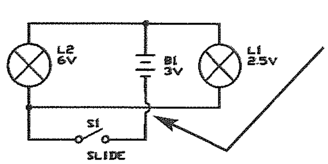




Schematics are easy to draw, and the part symbols used are international standards. Note that wires in a schematic are just lines, and can be as long as you like. Schematics are a flexible way of drawing circuits, and can be re-drawn in many different ways. For example, the above schematic could also be drawn as:

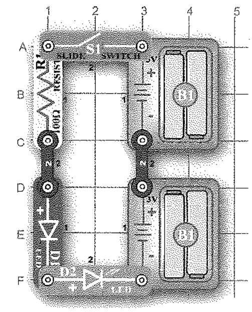


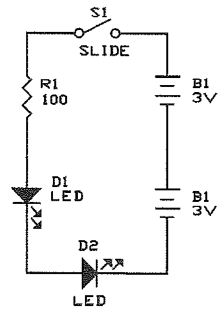


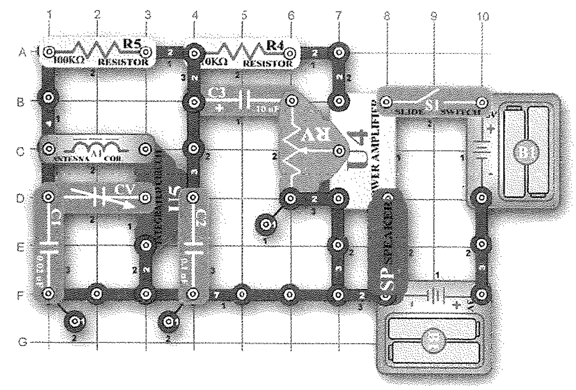


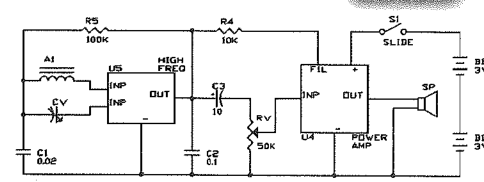
Note that ∩ represents two wires crossing over each other without connecting.

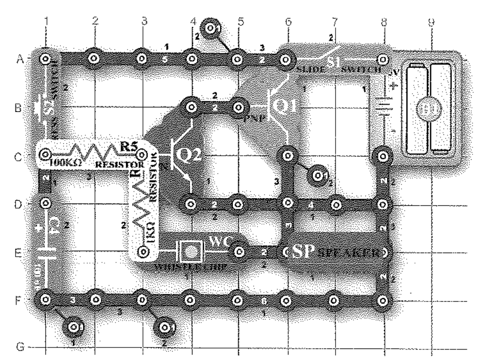
Here are some more schematic examples:

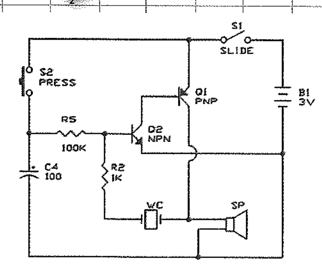












It is important to understand schematics, since many circuit designs are common and can be found in books. Almost all new circuits designed are similar to some circuit that already exists. Many products sold today come with schematics of their designs to assist in troubleshooting problems.

Quick Quiz

1. Draw a schematic for a circuit that consists of three lamps powered by a battery.
2. For each room in your home, make a schematic drawing showing how the lamps and switches controlling them are connected together.

Summary

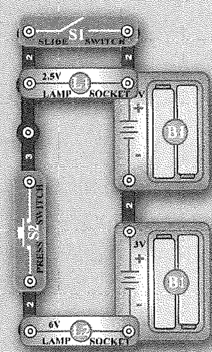
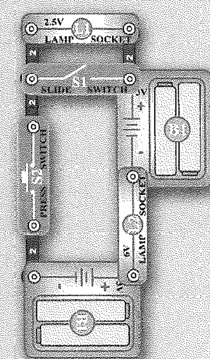
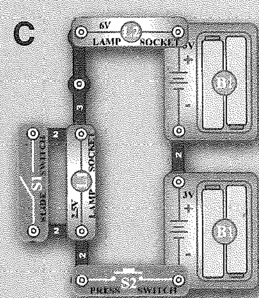
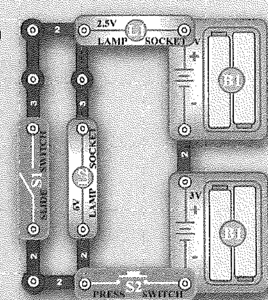
Summary of Chapter 1:

1. The electric current is a measure of how much electricity is flowing in a wire, and is expressed in Amperes.
2. The voltage is a measure of the electric pressure exerted into a wire or circuit by a battery or other power source, and is expressed in volts.
3. Switches are used to turn on or turn off the flow of electricity in a circuit.
4. A light bulb converts electricity into light.
5. Most electronic products have components mounted on circuit boards with the wires literally printed on the board surface.
6. Electrical circuits are all combinations of series and parallel configurations.
7. A short circuit is a no-resistance path across a power source, and causes damage to components and batteries.
8. Solder is a special metal that is melted to make solid electrical connections.
9. Schematics are engineering drawings of circuits using symbols.

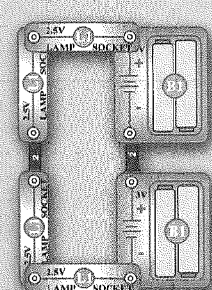
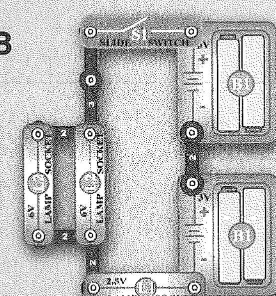
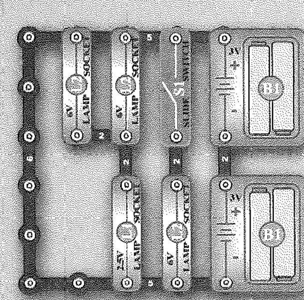
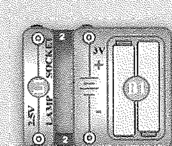
Quiz

Chapter 1 Practice Problems

1. The flow of electricity is measured in ___________.
   A. gallons B. minutes C. amperes D. volts
2. To turn on a switch, you ___________ it.
   A. voltage B. open C. pressurize D. close
3. Three of the choices below are the same circuit with the parts arranged in different ways. Which choice is a different circuit?

A

B

C

D


4. Which of these is a short circuit?

A

B

C

D


Answers: 1. C, 2. D, 3. D, 4. C